Is the Contingentist/Inevitabilist Debate a Matter of Degrees?[*]

Joseph D. Martin[†]

† University of Minnesota, Program in the History of Science, Technology, and Medicine; Minnesota Center for Philosophy of Science; mart1901@umn.edu

Abstract: Debates between contingentists and inevitabilists contest whether the results of successful science are contingent or inevitable. This paper addresses lingering ambiguity in the way contingency is defined in these debates. I argue that contingency in science can be understood as a collection of distinct concepts, distinguished by how they hold science contingent, by what elements of science they hold contingent, and by what those elements are contingent upon. I present a preliminary taxonomy designed to characterize the full range positions available and illustrate that these constitute a diverse array, rather than a spectrum.

1. Introduction

Ian Hacking, in *The Social Construction of What?*, asks his readers to assign themselves a number from one to five to describe how central contingency is to their personal conceptions of science. If you rate yourself at one, then you are a strong inevitabilitst, whereas if you choose five, you are highly contingentist and probably have strong constructionist sympathies (Hacking 1999, 99). In response, Léna Soler questions whether this is the correct approach, and asks: "should we introduce degrees of contingentism depending on the kind of contingent factors that are supposed to play a role?" (Soler 2008a, 223).

Herein, I answer Soler's question in the emphatic affirmative, and therefore the question posed in the title with a resounding "no." Contingency in science can be understood as a collection of distinct concepts, distinguished by how they hold science contingent, by what elements of science they hold contingent, and by what those elements are contingent upon. What separates one contingentist from another is not that one tags herself a two and the other fancies himself a five according with how strongly each believes science might have developed

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differently. Their disagreement arises from the fact that they understand contingency-producing factors to act differently on different aspects of the scientific process. Contingency is a "what" question, not a "how much" question.

Before beginning this discussion I review the contingentist/inevitabilist (C/I) debate in Section 2 by reconstructing positions the debate's central figures stake out. Ian Hacking, who coined the terms "contingentism" and "inevitabilism," figures centrally. I also discuss several scholars who were retrospectively cast as interlocutors in the debate, such as Andrew Pickering, Sheldon Glashow, and James Cushing, and those who responded to Hacking directly, namely Léna Soler and Howard Sankey. After demonstrating how their conceptions of contingency have defined the debate, I argue that the conversation wants for a clear understanding of contingency and suggest how this ambiguity might be clarified by more rigorous classification of the concepts it groups together.

Section 3 presents a detailed discussion of the nature of contingency in science, in which I outline a fresh taxonomy of the concept. The taxonomy builds on John Beatty's distinction between unpredictability contingency and causal dependence contingency (Beatty 2006). This distinction clarifies the debate substantially, but I argue that a second step is required. Further decomposing unpredictability contingency and sub-classifying causal dependence contingency—based on the things within science considered to be contingent and the factors they are presumed to be contingent upon—allows more precise characterization of the views under discussion. A detailed picture of ways different authors use contingency serves as a basis from which to examine how a nuanced account of the concept can clarify some persistent ambiguities in the C/I debate.

2. Contingency and Inevitability

Ian Hacking coined "contingentism" and "inevitabilism" in the same book in which he hinted that contingency might be understood as a spectrum. Contingency appears as a feature of his effort to understand the philosophical stakes of social constructionism. Hacking casts contingency as a sticking points between constructionists and their opponents. He identifies the constructionist program as seeking to undermine claims about the inevitability of ideas. When generalized, according to Hacking, the constructionist argument takes the form "X need not have existed, or need not be at all as it is, is not determined by the nature of things; it is not inevitable." It often proceeds to two other more advanced stages, which contend a) that X is bad in its current form, and therefore b) should be eliminated or radically altered (Hacking 1999, 6). The constructionist program meets irreconcilable opposition from inevitabilists when it claims that the results of scientific investigation are contingent, and therefore unconstrained by the structure and properties of the natural world.

Andrew Pickering, author of 1995's *Constructing Quarks*, is Hacking's paradigm contingentist. Pickering advanced the view that high energy physics' Standard Model resulted from an exegesis of data, which could have produced any one of numerous, ontologically incompatible interpretations. He concludes that physics might have escaped the twentieth century quark free, and that if it had, it would not be any less successful (Pickering 1984). Hacking interprets this argument in light of later work, *The Mangle of Practice* (Pickering 1995), wherein Pickering argued that scientific consensus arises from negotiation between theory applied to the world, theory applied to instruments, and the construction of the instruments themselves to develop a robust fit with observed data. The results of science are contingent from this perspective because the negotiation could be carried out in any number of ways, each resulting in the same degree of self-described success. Pickering's punch line is that twentieth-century physics could have been just as successful if, for example, cyclotrons had not supplanted traditional cloud-chamber technology and the resulting theory of the micro-world had not been dominated by quarks, which he contends are the peculiar progeny of the particle accelerator.

Hacking elaborates the inevitabilist stance in "How Inevitable Are the Results of Successful Science?," writing: "We ask: *If the results R of a scientific investigation are correct, would any investigation of roughly the same subject matter, if successful, at least implicitly contain or imply the same results?* If so, there is a significant sense in which the results are inevitable" (Hacking 2000, 61). Pickering would deny that equal success implies equivalence of any sort. By contrast, Hacking casts Sheldon Glashow as arch inevitabilist. Glashow holds that any investigation into the natural world starting from reasonable initial assumptions would produce not only the same answers, but also a similar set of questions to ask. Glashow imagines intelligent aliens as hypothetical scientists whose physical laws should be isomorphic with ours. In doing so, Hacking charges, Glashow tacitly makes crucial assumptions about the "reasonable" initial conditions necessary for alien science to produce the same results. How do we know, for example, that aliens would identify proton structure as an interesting question? Hacking segues from Glashow into the difficulties with strong inevitability claims: how stringently can you set the initial conditions before the argument dissolves into tautology? If the inevitabilist asserts that a successful alternate scientific enterprise will produce the same results by stipulating that success requires asking the same questions, using the same instruments to observe the same entities, and starting from the same assumptions, then we are left with the trivial observation that effectively identical scientific investigations produce effectively identical results (2000, 66).

Pickering and Glashow represent extremes; Hacking seeks a middle way. His compromise locates contingency at the level of the questions scientists ask. It is contingent, he argues, which questions are "live." Live questions are those that make sense within the contemporary theoretical framework. Once science satisfactorily answers a live question we can take that result to be inevitable in some meaningful sense, but we have no guarantee that it would have been asked in the first place.[1] Contingency, for Hacking, enters into science by allowing historical and socio-cultural factors to define what questions scientists find interesting and what questions they are allowed to ask. These questions are not necessarily answerable, and they might not make sense in any theory-independent sense, but once nature proves forthcoming with an answer, that answer has the tinge of inevitability. Science could have developed differently, but only because it could have addressed a different set of questions. Possible alternate results are never logically incompatible with current successful science (2000, 71).

When distinguishing contingency from inevitability, Hacking observes the debate's independence from the realism/anti-realism issue: "the contingency thesis itself is perfectly consistent with […] scientific realism, and indeed anti-realists […] might dislike the contingency thesis wholeheartedly," (Hacking 1999, 80). Howard Sankey (2008) maintains the same separation between the debates. He defends weak fallibilism, consistent with an inevitabilist viewpoint, holding that individual results of science are contingent—individual instances of scientific investigation are fallible—but we can be confident that statistically inevitabilist tendencies will wash out local contingencies.

Sankey defends his fallabilist stance's compatibility with a contingency thesis, which he says is an epistemic claim about scientific practice and the way investigators engage with the

[1] Hacking does not offer an account of just how scientists can determine when a live question has been adequately answered, an issue that is not unproblematic (see Galison 1987).

world: “Scientist might collect different evidence from the evidence they in fact do collect. They might have developed different instruments and techniques from the ones which have been developed and put to use” (Sankey 2008, 259). A geological example, the discovery of continental drift, illustrates his point: “The epistemic situation is […] dependent on contingent factors such as the availability of evidence and relevant knowledge, the development of instrumentation and the provision of research funding” (2008, 262). Sankey’s contingency differs from both Pickering’s and Hacking’s. Pickering would not contest that the factors Sankey identifies are contingent, but he would compile a list of additional contingencies much longer than Sankey would admit. Hacking argues for contingency of form rather than content of science: difference without incompatibility. Sankey points to the empirical content of science as contingent. These perspectives are not incompatible, but they have different emphases—Sankey focuses on evidence, Hacking on inquiry.

Sankey subtly contrasts James Cushing, who argues that contingency has an “ineliminable role in the construction and selection of a successful scientific theory from among its observationally equivalent and unrefuted competitors” (Cushing 1994, xi). Cushing uses “theory” equivocally, as his prime example is the choice between Bohr’s and Bohm’s interpretations of quantum mechanics, which can be construed as competing window dressings of the theory of quantum mechanics rather than as theories themselves. Quibbling aside, Cushing argues that choices between observationally equivalent theories are contingent. He does not claim that such choices are irrational, but that they are guided by philosophical and other external criteria. In the case of Bohm versus Bohr, the interpretive question hinges on whether one abandons strict determinacy or strict locality in the quantum realm. Evidence suggests that either particles in quantum states, obeying the probabilities assigned by their wave functions, assume classically observable values for their key properties—charge, spin etc.—during an observation event, or some "hidden variables" determine these properties, but instantaneous signaling across finite distances is permitted. The first violates an ingrained philosophical preference for deterministic processes in physics, while the second flaunts a tradition of skepticism about instantaneous action at a distance. Cushing's view, exemplified by the claim that the Bohmian view's defeat at the hands of Bohr's Copenhagen interpretation was contingent, involves no change in the empirical content of the theories in question. Nor does Cushingtonian contingency act on the data collection process—the crux of Sankey's argument.

Most who deploy contingency do so in pursuit of goals other than defining it. Sankey wants to show the independence of the C/I debate from discussions of realism. Léna Soler identifies this argument as a premature, writing: "the 'contingentism versus inevitabilism' contrast does not exist as an autonomous, well identified issue of significance," (Soler 2008b, 232). On the basis of this ambiguity she sets out to clarify the issue, employing a thought experiment involving two, isolated communities of physicists, starting with the same initial conditions, asking their own questions, unguided by the work of the other scientists:

> Human beings might have succeeded in developing a physics as successful and progressive as ours, and yet asked completely different physical questions from the ones that have actually been asked, with the result that the accepted answers—in other words the content of the accepted physical theories and experimentally established physical facts—would be at the same time robust and different from ours. (2008b, 232)

Any non-trivial contingency, Soler contends, requires that two isolated scientific communities starting from the same point produce "irreducibly different" results, while still satisfying a reasonable set of criteria for success (2008b, 232).

Soler's contingency involves deep and irreconcilable oppositions between competing physical theories. Given the constancy of the initial conditions in Soler's thought experiment, it tests only whether science is contingent irrespective of the initial conditions, and does not consider to what extent science might be contingent *upon* antecedent conditions.[2] Soler's thought experiment does not assess the relative contributions of contingency to the collection of internal and external factors that influence the trajectory of science.

Each scholar mentioned here questions how science might be contingent. In doing so, each employs a different understanding of what contingency means and at what point the claim becomes meaningful. They cast contingency in a qualitatively different ways rather than with differing intensities, representing diversity of kind, not of degree:

Hacking: *It is contingent what questions scientists decide are interesting.*

Pickering: *It is contingent what ontological entities scientists claim to find in the natural world.*

Glashow: *The theoretical structure of science is **not** contingent.*

Sankey: *It is contingent what instruments and techniques are available to scientists.*

Cushing: *It is contingent how scientists arbitrate between empirically equivalent theories.*

Soler: *Science is contingent only if it has available at least two equally successful, but irreducibly different paths from any given starting point.*

A smooth scale of contingentism cannot capture their differences, even superficially. The next section systematizes the diversity of views sheltered within the contingency concept.

3. Taxonomizing Contingency

3.1. A Preliminary Distinction

[2] Here I implicitly distinguish "contingent per se" from "contingent upon," borrowing from Beatty (2006). See Section 3 below for a more thoroughgoing discussion.

Contingency is a wildly diverse concept. How can we refine our understanding of contingency so it can be applied with less ambiguity? John Beatty offers a crucial distinction between “contingent per se” and “contingent upon” (Beatty 2006). “Per se” contingency describes stochasticity in the historical process; it implies that the process of history itself is *unpredictable*. “Upon” contingency requires no unpredictability, but rather describes a historical process that is far from robust with respect initial conditions, indicating that outcomes have a measure of *causal dependence* on the relevant antecedent factors. Any change in initial conditions could lead to a different outcome, even if the outcome of the process is, in principle, predictable from any given set of initial conditions.

In drawing this distinction, Beatty invokes Stephen J. Gould’s thought experiment: restart the story of evolution from the Cambrian explosion, and ask if “replaying the tape” in this way directs the history of life down a different path (Gould 1989). Gould argues that evolution is highly contingent, and the rerun would differ dramatically from the initial broadcast. As Beatty observes, Gould alternates between the unpredictability and causal dependence senses of contingency. Beatty argues that these two conceptions are compatible, but have different consequences for our understanding of the historical process.

How should recognizing the distinction between these two varieties of contingency inform the C/I debate? Take Pickering: his 1984 claim that physics might have proceeded in a direction that did not include quarks is an unpredictability claim about scientific knowledge. He holds there that scientific knowledge is contingent per se. His view as reinterpreted by Hacking is an “upon” contingency claim. If the response to new data is a negotiation between existing theories, auxiliary theories about instruments, and the instruments themselves, then the consequent theory is contingent upon each of those three factors. In the second version of the argument, Pickering's stance gets its bite from the factors it identifies as causally relevant rather than from the unpredictability of the scientific process.

Hacking, Soler, and Sankey, all observe that even the strongest inevitabilist admits that a benign form of historical contingency shapes the course of science. The Bragg family might have gone into sheep shearing rather than physics, and the resulting disturbance in the development of x-ray crystallography would likely have substantially altered the story of the discovery of DNA's structure. The Cold War might have dragged on a few years longer, the United States Congress might have been friendlier towards basic research expenditures, the Superconducting Super Collider might have been built, and high energy physicists might no longer be looking for the Higgs boson. In Beatty's language, inevitabilists are happy with the claim that scientific knowledge is contingent upon some historical factors, while denying the stronger claim that it is contingent per se.

Beatty's distinction substantially clarifies disagreements between inevitabilists and contingentists. They do not disagree about *the extent to which* scientific knowledge is contingent; they disagree about *what kind of* contingency influences the scientific process. Contingentists, as described by Hacking, admit both unpredictability and causal dependence contingency, while inevitabilists see no trouble from some types of causal dependence contingency, but draw the line at its more consequential sibling. This distinction does not exhaust the possible positions in the contingency debate. It demonstrates that Hacking's method of rating contingency on a spectrum inadequately describes the commitments involved, but it only begins to capture the full range contingency claims available. Those who allow causal dependence contingency might have reasonable disagreements about what aspects of science are subject to contingency claims and what science can be reasonably said to be contingent upon.

3.2. Towards a Taxonomy of Contingency

Each of Beatty's categories might be decomposed further. First, consider unpredictability contingency. Beatty defines it as the belief that "the occurrence of a particular prior state is *insufficient* to bring about a particular outcome," (Beatty 2006, 339). It appears that the unpredictability contingentist makes a strong metaphysical claim about the historical process: it is indeterministic. Indeed, Gould does appear to be making such indeterminacy claims. Should we replay the exact same tape of life from the exact same initial conditions and get a different result, then the process by which life develops exhibits intrinsic stochasticity.

Indeterminacy is not, however, the only way to understand per se contingency. Beatty observes that contingency is the lynchpin of Gould's argument that selection should not be the only causal agent evolutionary biologists invoke to explain the features and behaviors of present-day organisms (see Gould and Lewontin 1979). This suggests that unpredictability, as applied to contingency, can be understood as a methodological argument. This weaker understanding would suggest that outcomes are contingent (per se) *with respect to* some specified set of causal factors. It does not rule out the ability of other causal factors to provide an exhaustive, deterministic explanation. In fact, it often suggests such factors. Such is Gould's case against what he calls pan-selectionism—the assumption that selection can be invoked to explain any feature of an organism. The weaker version of unpredictability contingency he employs suggests that the features of organisms are contingent (unpredictable) *with respect to* selection effects. Such a view is consistent with deterministic evolution; it merely implies that factors other than selection are partly responsible.

The strong version of unpredictability contingency, which we might call indeterminist contingency, implies randomness in the historical process. The weaker version, incompleteness contingency, claims that some set of causal factors is inadequate offer a complete explanation of the historical process, and that outcomes are unpredictable with respect to that set of factors. These two forms do different types of philosophical work. Indeterminist contingency says something about how the world is. Incompleteness contingency brands a set of explanatory tools inadequate, and so depends on the state of scientific practice and must refer to established explanatory orthodoxy.

Causal-dependence contingency is a more complicated case than unpredictability because the objects of "upon" might be expounded *ad nauseam*. The first step towards a classification requires identifying suitably distinct parts of science that might be held contingent. Science, like contingency, is heterogeneous and the claim that science is contingent can mean different things depending on what parts of science that claim specifies. Science makes ontological claims, formulates methodological procedures, develops models, adopts interpretations, and builds communities. Causal dependence contingency can be initially differentiated based on which of these many aspects of science are claimed contingent. I propose five categories:

(1) *Trivial contingency* – Science is part of a historical process, and so is contingent in the same way human history is contingent. This weak claim covers individual scientists and the details of their everyday existences.

All non-Laplacian parties are happy to admit this form of contingency. A claim that science is contingent in the trivial sense, however, offers the hard-boiled contingentist little succor. Trivial contingency is agnostic about the aspects of science that are typically of interest to philosophers, and so has little bearing on the debate. This type of contingency is frequently invoked to argue that contingency need not be repugnant to the sophisticated inevitabilist. Sankey, for instance, argues that continental drift did not gain traction within the geology community until the 1950s and 1960s, when the U.S. Department of Naval Research began funding ocean floor research to bolster its submarine program (Sankey 2008, 262). Naturally, if the research had not been funded, and had not been conducted, the trajectory taken by the science would have been different, but this does not bear on the claim that successful science should pass through stages resembling ours. Trivial contingency alters the route science takes, but remains silent about its destination.

(2) *Sociocultural contingency* – The social structures that constitute scientific activity and science's interaction with culture are contingent.

At first glance this slightly stronger form of contingency might seem similarly innocuous. Like trivial contingency, it is agnostic about the content of science, acting instead on institutions, disciplines, communities, political relationships, and laboratory cultures. It is more complicated than trivial contingency, however, because it is the point where some strong contingentists dig in their heels. Forms of contingency that cut closer to the bone (see below) often rest on social determinism. A contingentist claiming that theoretical entities are contingent upon (causally determined by) social structures might want to deny that those social structures are themselves contingent. Similarly, inevitabilists might flinch when sociocultural contingency is used in conjunction with a stronger form, as in, for example, the controversial Forman thesis, which asserts that quantum indeterminacy was contingent upon the distinctive social conditions of the Weimar Republic (Forman 1971).

(3) *Methodological contingency* – The way in which we do science might have been different. This moderately weak variety holds experimental and theoretical techniques, laboratory practice, instruments, apparatus, and heuristic devices contingent.

Contingency claims frequently target the way science functions. Sankey approximates this version of contingency when he describes evidence collection and instrumentation as sources of contingency and claims that the development of plate tectonics could only come about when specific instrumentation came into common use (Sankey 2008). Many historical studies have examined how tool selection influences the way theories develop. The literature on model organisms is an obvious example. Robert Kohler's *Lords of the Fly* contends that the choice of *drosophila melanogaster* as the model organism for experimental genetics shaped the field's development (Kohler 1994). Experimental apparatus influences the collection, packaging, and inflection of data, while the available mathematics, heuristics, and analogies guide how that data is analyzed. This type of contingency is not trivial, but it does not directly imply incompatibilities between existing science and science that might have proceeded with different experimental or analytical tools. As with sociocultural contingency it can be combined with more potent forms.

(4) *Interpretive contingency* – The way in which we expound data in order to fill theoretical gaps is contingent.

Understanding theoretical implications requires interpreting data. Data, even if they motivate a particular theory, often do not compel one interpretation of that theory. Take Cushing's claim about the contingency of the Copenhagen interpretation: Quantum mechanics allows multiple logically consistent interpretations of what happens when quantum systems are observed. Building a satisfying ontological explanation requires physicists to interpret measurements that, by the very nature of the theory, do not provide the whole story. Given this necessary appeal to factors other than data, the interpretation we choose is contingent upon the context in which the theory emerges, and an alternate interpretation might well have emerged given different conditions (Cushing 1994).

(5) *Theoretical contingency* – This is the strongest form of contingency. In the constructionist mold, it holds that scientific theories themselves and the claims they make about the world, are contingent.

This form postulates deep incompatibility between two possible scientific trajectories. While theoretical contingency can be parsed in "upon" syntax, it approximates a per se claim. The main difference between theoretical contingency and the in-principle unpredictability of scientific results is the frequent postulation by its advocates of a causal arrow from specific historical or cultural factors to theories. Forman's argument that cultural instability in the Weimar Republic compelled physicists to accept indeterminacy, for instance, makes quantum mechanics' ontological claims contingent upon the Weimar cultural environment (Forman 1971). This is not the same as describing science as unpredictable, but the factors on which it is contingent make the claim equivalent with the incompleteness contingency claim that science is unpredictable from internal factors alone. The per se claim and the theoretical contingency claim often go hand in hand, as the argument often holds that theoretical contingency works *because* theory is either almost infinitely malleable (indeterminist), and/or subject to pressures that are currently underappreciated (incompleteness).

It might appear that this constitutes a spectrum given a description beginning with "trivial" and graduating into increasingly more serious claims, but the relationships between the elements are not so straightforward. Trivial contingency does not require a commitment to any of the other four, and theoretical contingency often implies several of the others a fortiori, but middle-of-the-road contingency claims cannot be so easily ranked. It would be consistent to hold an inevitabilist stance about methodology, arguing that mature science motivates an optimal form of investigation and modeling, while maintaining interpretive contingency. It would be equally consistent to be inevitabilist about interpretation while contingentist about methodology. These examples elucidate why contingency is a "what sort" question as opposed to a "how much" question. If I claim that one part of the scientific process is contingent while holding that another is not, that does not make me more or less contingent than I would be if I held the inverse view.

The categories above provide only half the picture. To complete the taxonomy a second layer is required. Distinctions based on what parts of science are contingent are critical, but we can also, invoking Beatty, draw further distinctions based on what they consider those factors to be contingent upon. Thus, while two people might agree that the methodological components of science are contingent, they might also disagree substantively about the factors upon which methodology is contingent. The factors upon which science, in all its aspects, might be contingent map onto the aspects that can themselves be held contingent: everyday events, sociocultural contexts, methods, interpretations, theories.

4. Summary

I have argued that the debate between contingentists and inevitabilists can be recast as an array of positions that directly oppose one another only over a small range of their total implications. Within the framework provided by Beatty, I have decomposed contingency into seven types, two under unpredictability and five under causal dependence. Each of these latter five might be further decomposed based on the "upon" relation of the contingency in question. These views of contingency can be held alone or in conjunction with others, and each combination constitutes a distinct position, which carries different assumptions about how science engages with the natural world.

Statements that science is contingent or inevitable are cumbersome when not identifying the area of science on which that property acts and specifying how that property operates within it. Science might be interpretively contingent without being methodologically contingent. It might be both without being theoretically contingent. Many processes play a role in the production of scientific knowledge. Contingency may enter through many doors; it will adopt a different character, with different consequences, when entering through each. The framework I have outlined demonstrates how science can be considered contingent and inevitable in qualitatively different ways and exposes assumptions about the causal structure of the scientific process that would otherwise remain implicit.

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